I declare, under penalty of perjury, that the foregoing is true and correct. Executed on May 31, 1996

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Norsworthy and Berndt's Time Series Analysis of the Bush-Uretsky Methodology

The essence of the Norsworthy-Berndt critique of the Bush-Uretsky methodology is their claim that time series analysis (known as cointegration tests) of the regression equations used by Bush and Uretsky and myself lead to the conclusion that all of the regression results are spurious.

In this appendix I make two main points. First, I demonstrate that the time series analysis of Norsworthy and Berndt is in fact an attack on the Bush-Uretsky methodology. This point is made most vividly by the fact that Norsworthy and Berndt reject as spurious regressions that are identical to those estimated by Bush and Uretsky[12].

Second, I show that one-half of the cointegration tests of Norsworthy and Berndt are applied incorrectly. They incorrectly apply econometric principles and ignore warnings contained in the manuals of the very computer program they utilize.

(a) Norsworthy and Berndt Reject the Bush-Uretsky Appendix F Results as Spurious

In tables A-7 to A-10 of their Reply Statement Norsworthy and Berndt use the Engle-Granger Cointegration Tests to test the residuals from what they call the "Fuss model" for unit roots. Of course it is not the Fuss model they test, but rather the Bush-Uretsky model, where some of the equations were modified by me by changing the form of the divestiture dummy variable. For clarity, it is useful to concentrate on the following equations which Norsworthy and Berndt label:

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[12] For obvious reasons, Norsworthy and Berndt choose to ignore this fact.

(1). Model: CPT C CPE DIVEST MOODY   (Table A-7)
(2). Model: CPT C CPE D84   MOODY   (Table A-7)
(3). Model: CPDIFF C DIVEST MOODY   (Table A-7)
(4). Model: CPDIFF C D84 MOODY   (Table A-8)
(5). Model: NPT C NPE D84 MOODY   (Table A-9)
(6). Model: NPDIFF C D84 MOODY   (Table A-10)

From Tables A-7 to A-10 it can be seen that the unit root hypothesis for models (1)-(6) cannot be rejected at the conventional 5% significance level used by Norsworthy and Berndt. This fact is noted by Norsworthy and Berndt (page 24). Hence according to Norsworthy and Berndt, these models are not cointegrated, and "[t]he inferences from those regressions are therefore likely to be invalid." (page 23)

Models (1) and (3) are the exact Bush-Uretsky equations estimated using the Bush-Uretsky data[13]. Models (2),(4),(5) and (6) are also the exact Bush-Uretsky equations, where the name of the divestiture dummy variable has been changed from DIVEST to D84. However, DIVEST and D84 are the exact same variables. This fact can be verified by comparing the cointegration statistics for models (1) and (2) in table A-7. They are identical. The cointegration statistics for model (3) from table A-7 and model (4) from table A-8 are also identical for the same reasons.

Since Norsworthy and Berndt have found that the Bush and Uretsky equations are not cointegrated, logically they cannot disagree with the following adjustment I have made to their summary statement on page 25: "In summary, the equations that Bush and Uretsky estimate are, by standard statistical criteria, inappropriate for their intended use: inference

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[13] Strictly speaking, the Bush-Uretsky data only cover the periods 1949-1992 and 1960-1992 whereas Norsworthy and Berndt include the 1993 data point in their regressions. However, excluding the 1993 data point has no effect on the cointegration tests of models (1)-(6).

about the shift in the input price differential. ... The results <u>Bush and Uretsky</u> obtained,

therefore, contribute nothing to our understanding of the input price differential"[14].

(b) <u>One-Half of Norsworthy and Berndt's Cointregration Tests Are Incorrect</u>

The test statistics used to test for cointegration require that the dependent variable and

at least one of the independent variables be integrated of order one (I(1)). When this

condition is not met, test statistics such as the Dickey-Fuller statistic used in the Engle-

Granger (tau) Test[15] have unknown distributions and any attempt to test for the absence of

cointegration is meaningless.

This requirement is made clear in the manuals which accompany the computer

program TSP 4.3 used by Norsworthy and Berndt to perform their cointegration tests.

> "The cointegration of time series is a methodology for the analysis of time
> series pioneered by Engle and Granger (1987). Two or more series are said to
> be *cointegrated* if a linear combination of them is I(0) (is stationary or has all
> roots inside the unit circle) even though individually they are each I(1). Thus
> the hypothesis of cointegration consists of two parts: tests for I(1) of the
> individual series and I(0) of a linear combination. Usually the term
> cointegration testing refers only to the second part of the hypothesis; <u>the test is
> performed *conditional* on the fact that each component series is I(i)."</u> (italics
> in original, underlining emphasis added)

> User's Guide, TSP Version 4.3, March 1995, page 94.

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[14] Contrast this statement with their earlier statement regarding the Bush-Uretsky regression results: "Our
conclusion thus confirms the findings of Commission economists Bush and Uretsky,..." (page 6). Clearly the left
hand does not acknowledge what the right hand is doing.

[15] This is the test used by Norsworthy and Berndt.

"The Engle-Granger Test is only valid if all the cointegrating variables are I(1); hence the default option to perform unit root tests on the individual series to confirm this before running the Engle-Granger test." (emphasis added)

Reference Manual, TSP Version 4.3, May 1995, page 40.

Norsworthy and Berndt perform the required unit root tests on the individual series in tables A-5 and A-6. The series CPDIFF and NPDIFF (the LEC-US input price differential growth rates) fail the unit root tests at the 5% significance level used by Norsworthy and Berndt[16]. This fact is acknowledged by Norsworthy and Berndt on page 23: "Unit root tests of the variables... reveal relatively high probabilities of unit roots for all variables except for CPDIFF and NPDIFF..." Hence the series CPDIFF and NPDIFF are not I(1) as required, and cointegration tests involving these variables are invalid (see above quotes from the TSP manuals). Tables A-8 and A-10 of the Norsworthy and Berndt reply, which involve CPDIFF and NPDIFF, are filled with invalid tests. As a result, one-half of the tests done by Norsworthy and Berndt are performed incorrectly.

Since CPDIFF and NPDIFF are stationary variables, the regressions using these variables as dependent variables are not subject to the claim that the results might be spurious. They remain legitimate regressions and can be used to test whether the temporary or permanent change hypothesis best represents the input price differential data.[17]

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[16] The p-values of the tests are .01 and .0008 respectively.

[17] The right hand side variables (including the dummy variables DIVEST and D90) are I(1). While the presence of unit roots implies that these variables are non-stationary, the asymptotic test statistics remain valid. This occurs because it is reasonable to assume that the right hand side variables remain fixed in repeated samples, since none of them are trending without limits.

Analysis of the Norsworthy-Berndt Attempt to Define a Measure of TFP Growth for Interstate Access Services

In section C, pages 32-33 of their Statement, Norsworthy and Berndt derive an equation (equation (3)) which they claim demonstrates how to separate TFP growth for interstate services from that for other services. Equation (3) is based on equation (2) (page 32), which contains a basic algebraic error that completely invalidates equation (2) and hence also invalidates equation (3) and their ultimate conclusion.

The first part of equation (2) contains the statement

$$\Delta TFP_{ALL\ SERVICES} = \Delta(Y_C/X_C) = \Delta Y_C/\Delta X_C \qquad \text{(B1)}$$

where the subscript C indicates a total company variable.

While the first equality is just the definition of the growth in total company TFP from year t-1 to year t, the second "equality" represents a fundamental error in algebra; the two expressions are not equal. This can be seen from a simple numerical example. Suppose we obtained the following data on aggregate output Y_C and aggregate input X_C for two years.

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Time Period	Aggregate Output Y_C	Aggregate Input X_C
Year 1	200	100
Year 2	500	200

$$\Delta TFP_{\text{ALL SERVICES}} = \Delta(Y_C/X_C) = [500/200 - 200/100] / [200/100] = 0.25$$

Now consider the calculation of the right hand side of (B1).

$$\Delta Y_C/\Delta X_C = [(500-200)/200] / [(200-100)/100] = 1.50$$

Clearly $\Delta(Y_C/X_C) \neq \Delta Y_C/\Delta X_C$ and equation (2) of Norsworthy and Berndt is an invalid construction. Since equation (3) depends on equation (2) for its validity, it is also invalid. Hence Norsworthy and Berndt have not demonstrated the analytical possibility of calculating TFP for interstate access services in an economically meaningful way.[18]

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[18] For the numerical example contained in the table, the company TFP growth rate between the two years is $(.25)*100 = 25\%$. If Norsworthy and Berndt's equation (2) had been used in the calculation, the company TFP would have been estimated as $(1.50)*100 = 150\%$, a large overestimate of the correct value. If the more conventional "difference in logarithms" method had been used to calculate the growth rates, the two TFP growth calculations would have been 22% and 132% respectively.

Cost Complementarity and the Calculation of TFP Growth for Interstate Services

Dr. Nadiri introduces the idea that if the degree of local cost complementarity between the two services is constant, then their costs are not joint and separate TFP growth rates can be calculated for each service (pages 14-15 of his statement). This idea is incorrect.

Local cost complementarity occurs between two outputs if a small increase in the supply of one output reduces the marginal cost of the other output. Consider the following simple example of a joint cost function for two outputs (y_1 and y_2):

$$C(y_1, y_2) = \alpha_1 y_1 + \alpha_2 y_2 + \alpha_{11} (y_1)^2 + \alpha_{22} (y_2)^2 + \alpha_{12} y_1 y_2 \qquad (C.1)$$

where C is total cost and $\alpha_1, \alpha_2, \alpha_{11}, \alpha_{22}$ and α_{12} are parameters of the cost function. The term which measures local cost complementarity is $\alpha_{12} y_1 y_2$, since if this term did not exist, costs would be non-joint, and a conceptually meaningful cost allocation could be accomplished.[19]

Nadiri does not define what he means by "the degree of local cost complementarity". Local cost complementarity is usually calculated as $\partial^2 C / \partial y_1 \partial y_2$, and I will assume this is what he meant by degree of local cost complementarity. For the example developed in this footnote, this derivative is equal to α_{12}, which is a constant. This fact can be seen as follows.

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[19] Costs allocated to output one would be $\alpha_1 y_1 + \alpha_{11} (y_1)^2$ and costs allocated to output two would be $\alpha_2 y_2 + \alpha_{22} (y_2)^2$.

Marginal cost for output one is calculated as

$$\partial C / \partial y_1 = \alpha_1 + 2\,\alpha_{11}\,y_1 + \alpha_{12}\,y_2 \tag{C.2}$$

The degree of local cost complementarity is thus calculated as

$$\partial / \partial y_1\,(\partial C / \partial y_1) = \partial^2 C / \partial y_1 \partial y_2 = \alpha_{12}$$

The degree of local cost complementarity is constant, but costs are joint (unless $\alpha_{12} = 0$, the case of zero cost complementarity and non-joint production) and separate TFP growth rates for the two services cannot be calculated in an economically meaningful way. Hence Nadiri's statement that a constant degree of local cost complementarity implies non-joint costs is incorrect.

Analysis of ETI's Claim That the 1990 Data Point Should Be Dropped From the Sample

ETI claims that the 1990 data point is an outlier and hence should be dropped from the sample. There are two classifications of outliers which are possible. First, a data point may be an outlier independent of the model being estimated. This would occur if it were known that the data point had been calculated incorrectly, or recorded in error, or there was a change in the basic underlying data generating process which made that data point non-comparable with the rest of the sample. Second, a data point may be an outlier *relative to a particular model*. This would occur if the model had difficulty explaining that particular data point.

There is no evidence in these proceedings that the 1990 data point satisfies the first definition of an outlier. (ETI does not even make this claim.) Hence we need to explore the possibility that it satisfies the second definition; and if it does, determine the implications for testing the temporary change hypothesis versus the permanent change hypothesis.

Econometricians have developed a procedure to test for the possible existence of model-related outliers. It is known as the theory of influential outliers.[20] There are a number of stages to the testing procedure. First, using a specific model, a regression is performed with the potential outlier deleted from the sample. Second, the residuals from this regression are tested for normality. Third, conditional on acceptance of normality, a studentized residual is formed for the potential outlier and this residual is compared with the

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[20]An accessible description of this theory and the resulting test procedures can be found in the econometrics textbook Judge et al. (1988), chapter 22.

value of 2. If the residual is greater than 2, the observation is classified as an outlier, otherwise it is not an outlier.[21]

If the observation is not an outlier, the process terminates - there is no evidence the observation should be deleted from the sample. If the observation is an outlier, it is analyzed further to see whether it is influential. In the current context, an outlier will be influential if dropping it from the sample changes the decision regarding the choice between the temporary and permanent change hypotheses.

When testing competing hypotheses using the non-nested hypothesis testing procedure, it is possible that a data point will have a studentized residual greater than 2 conditional on one hypothesis, and less than 2 conditional on the other hypothesis. In such a case the data point cannot be considered an outlier, since to do so would bias the test in favour of the hypothesis for which the studentized residual is greater than 2. Under these circumstances, a data point is considered an outlier only if it has studentized t values greater than 2 conditional on both competing hypotheses.

In conducting the tests I will use the Christensen 1 data set used by ETI in its critique of my analysis. I will also analyze the Cox tests since these are the only ones considered by ETI. Finally, I will present results for both the case where CPT is the dependent variable and where CPDIFF is the dependent variable. Recall that the regression where CPT is the dependent variable (the only regression considered by ETI) may be spurious and so results from that regression should be viewed with suspicion.

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[21] Judge et al (1988), page 894, express this test as follows: "Studentized residuals that have values that could reasonably come from a t-distribution, say less than 2 in absolute value, are regarded as acceptable in terms of the model specification. Others are regarded as outliers."

Table D-1 contains values of the Bera-Jarque statistic used to test for normality of the errors.[22] This statistic is chi-squared with two degrees of freedom under the null hypothesis of normality. Hence the 5% significance level critical value is 5.99. Since all the values in Table D-1 are less than 5.99, normality is accepted and we can continue with the testing procedure. Table D-2 contains values of the studentized residuals for 1990. The studentized residuals are greater than 2 for the permanment change hypothesis, but less than 2 for the temporary change hypothesis. We are in the situation discussed above, where to claim that the 1990 data point is an outlier would be to bias the non-nested hypothesis test in favour of the permanent change hypothesis. Hence the 1990 data point is not an outlier, and the ETI procedure of dropping this data point from the analysis is invalid. The conclusion in my first declaration, that the permanent change hypothesis is rejected by the data whereas the temporary change hypothesis is not rejected, continues to be valid.

In spite of the fact that it is not valid to drop the 1990 data point from the analysis, I now go on to consider the effects of doing so on the non-nested testing results. I carry out this invalid procedure to demonstrate the selectivity bias which permeates ETI's criticism of my earlier analysis.

Tables D-3 and D-4 present the complete set of test results for the Christensen 1 data set through 1992 and 1993 respectively. These tables preserve the format of tables A.5 and A.6 of my initial declaration. The numbers with asterisks are the test results reported by ETI in their tables A10 and A11.

A consideration of the entries in my tables D-3 and D-4 demonstrate how selective

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[22] See Judge et al. (1988), pages 890-92 for a description of this test statistic.

and misleading are the results reported by ETI. For the possibly spurious regression (CPT as the dependent variable), as noted in the ETI evidence, the temporary change hypothesis is rejected. This is not surprising given the fact that the test is biased against this hypothesis (see the earlier influential outliers analysis). However, what ETI chose not to report is the fact that the permanent change hypothesis is also rejected, despite the fact that the test is biased in favour of this hypothesis.

The Cox Test results for the regression with CPDIFF as the dependent variable are not reported by ETI in their tables A9 and A10, in spite of the fact that they report corresponding results for all earlier analyses (tables A4, A5, and A8). The results they chose not to report are damaging to their viewpoint. For both the 1949-92 and 1949-93 data sets the permanent change hypothesis is rejected. Only for the 1949-93 data set is the temporary change hypothesis rejected. It is not rejected for the 1949-92 data set, which was the data set used by Bush and Uretsky. Thus, even though the test is biased in favour of the permanent change hypothesis, the permanent change hypothesis does not perform as well as the temporary change hypothesis.[23]

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[23] For the Christensen 2 (NERA) data set and the non-spurious regression (NPDIFF as the dependent variable) the temporary change hypothesis is accepted for both the 1949-92 and 1949-93 data sets. The permanent change hypothesis continues to be rejected. In this case there is no bias in the test since the 1990 data point is an outlier with respect to both hypotheses. However, it is not an influential outlier since dropping the 1990 data point does not affect the decision that the permanent change hypothesis is rejected and the temporary change hypothesis is accepted.

Table D-1

Tests of the Normality Requirement: 1949-1992

Hypothesis	Dependent Variable	
	CPT	CPDIFF
Temporary Change	0.69	1.48
Permanent Change	0.70	0.99

Tests of the Normality Requirement: 1949-1993

Hypothesis	Dependent Variable	
	CPT	CPDIFF
Temporary Change	0.61	1.71
Permanent Change	0.59	0.87.

Table D-2

Studentized Residuals for the 1990 Data Point: 1949-1992

Hypothesis	Dependent	Variable
	CPT	CPDIFF
Temporary Change	1.60	1.81
Permanent Change	3.68	3.29

Studentized Residuals for the 1990 Data Point: 1949-1993

Hypothesis	Dependent	Variable
	CPT	CPDIFF
Temporary Change	1.65	1.84
Permanent Change	3.71	3.30

Table D-3

Testing the Two Competing Hypotheses Using the Cox Test
Data to 1992 (1990 Data Point Excluded)

Data Set and Equation Nos.	Hypothesis	Standard Normal Statistic (N) for α	Critical 5% Value of N	P-Value
Christensen Eqs (2)&(4)	H1 is correct	-2.49	-1.96	.0126
(CPT is dependent variable)	H2 is correct	-2.25*	-1.96	.0244
Christensen Eqs (3) &(5)	H1 is correct	-2.05	-1.96	.0400
(CPDIFF is dependent variable)	H2 is correct	-1.25	-1.96	.2095

* This is the only test statistic which ETI presents in its incomplete version of the non-nested hypothesis test (table A10).

Table D-4

Testing the Two Competing Hypotheses Using the Cox Test
Data to 1993 (1990 Data Point Excluded)

Data Set and Equation Nos.	Hypothesis	Standard Normal Statistic (N) for α	Critical 5% Value of N	P-Value
Christensen Eqs (2)&(4)	H1 is correct	-2.34	-1.96	.0194
(CPT is dependent variable)	H2 is correct	-3.77*	-1.96	.0002
Christensen Eqs (3) &(5)	H1 is correct	-2.09	-1.96	.0364
(CPDIFF is dependent variable)	H2 is correct	-2.08	-1.96	.0372

* This is the only test statistic which ETI presents in its incomplete version of the non-nested hypothesis test (table A11).